CHEMISTRY I
for PRE-UNIVERSITY

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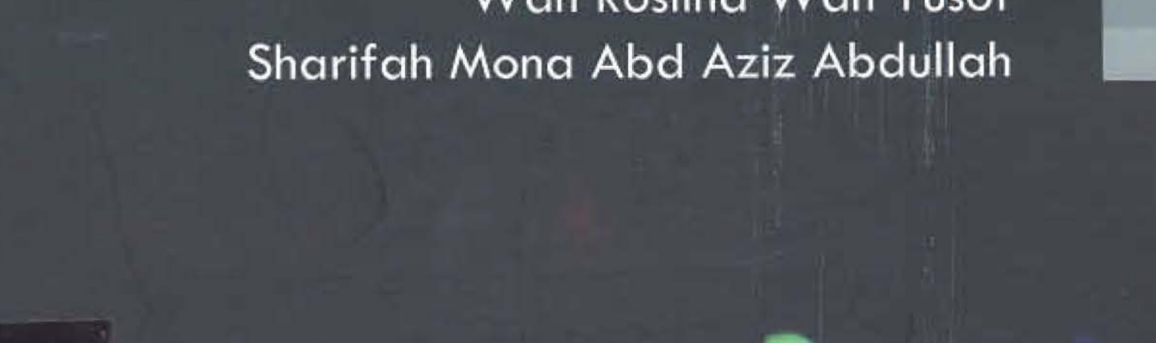

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The Periodic Table of Elements

Key

Relative Atomic Mass
Atomic Symbol
Name
Atomic Number

Metals
Nonmetals
Metalloids

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1.0 **H** Hydrogen 1																	4.0 **He** Helium 2
6.9 **Li** Lithium 3	9.0 **Be** Beryllium 4											10.8 **B** Boron 5	12.0 **C** Carbon 6	14.0 **N** Nitrogen 7	16.0 **O** Oxygen 8	19.0 **F** Fluorine 9	20.2 **Ne** Neon 10
23.0 **Na** Sodium 11	24.3 **Mg** Magnesium 12											27.0 **Al** Aluminium 13	28.1 **Si** Silicon 14	31.0 **P** Phosphorus 15	32.1 **S** Sulphur 16	35.5 **Cl** Chlorine 17	39.9 **Ar** Argon 18
39.1 **K** Potassium 19	40.1 **Ca** Calcium 20	45.0 **Sc** Scandium 21	47.9 **Ti** Titanium 22	50.9 **V** Vanadium 23	52.0 **Cr** Chromium 24	54.9 **Mn** Manganese 25	55.8 **Fe** Iron 26	58.9 **Co** Cobalt 27	58.7 **Ni** Nickel 28	63.5 **Cu** Copper 29	65.4 **Zn** Zinc 30	69.7 **Ga** Gallium 31	72.6 **Ge** Germanium 32	74.9 **As** Arsenic 33	79.0 **Se** Selenium 34	79.9 **Br** Bromine 35	83.8 **Kr** Krypton 36
85.5 **Rb** Rubidium 37	87.6 **Sr** Strontium 38	88.9 **Y** Yttrium 39	91.2 **Zr** Zirconium 40	92.9 **Nb** Niobium 41	95.9 **Mo** Molybdenum 42	(98) **Tc** Technetium 43	101.1 **Ru** Ruthenium 44	102.9 **Rh** Rhodium 45	106.4 **Pd** Palladium 46	107.9 **Ag** Silver 47	112.4 **Cd** Cadmium 48	114.8 **In** Indium 49	118.7 **Sn** Tin 50	121.8 **Sb** Antimony 51	127.6 **Te** Tellurium 52	126.9 **I** Iodine 53	131.3 **Xe** Xenon 54
132.9 **Cs** Caesium 55	137.3 **Ba** Barium 56	138.9 **La*** Lanthanum 57	178.5 **Hf** Hafnium 72	180.9 **Ta** Tantalum 73	183.8 **W** Tungsten 74	186.2 **Re** Rhenium 75	190.2 **Os** Osmium 76	192.2 **Ir** Iridium 77	195.1 **Pt** Platinum 78	197.0 **Au** Gold 79	200.6 **Hg** Mercury 80	204.4 **Tl** Thallium 81	207.2 **Pb** Lead 82	209.0 **Bi** Bismuth 83	(209) **Po** Polonium 84	(210) **At** Astatine 85	(222) **Rn** Radon 86
(223) **Fr** Francium 87	(226) **Ra** Radium 88	(227) **Ac**** Actinium 89	(261) **Rf** Rutherfordium 104	(262) **Db** Dubnium 105	(266) **Sg** Seaborgium 106	(264) **Bh** Bohrium 107	(277) **Hs** Hassium 108	(268) **Mt** Meitnerium 109	(271) **Ds** Darmstadtium 110	(272) **Rg** Roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide Series	140.1 **Ce** Cerium 58	140.9 **Pr** Praseodymium 59	144.2 **Nd** Neodymium 60	(147) **Pm** Promethium 61	150.4 **Sm** Samarium 62	152.0 **Eu** Europium 63	157.2 **Gd** Gadolinium 64	158.9 **Tb** Terbium 65	162.5 **Dy** Dysprosium 66	164.9 **Ho** Holmium 67	167.3 **Er** Erbium 68	168.9 **Tm** Thulium 69	173.0 **Yb** Ytterbium 70	175.0 **Lu** Lutetium 71
** Antinide Series	232.0 **Th** Thorium 90	(231) **Pa** Protactinium 91	238.0 **U** Uranium 92	(273) **Np** Neptunium 93	(242) **Pu** Plutonium 94	(243) **Am** Americium 95	(247) **Cm** Curium 96	(245) **Bk** Berkelium 97	(251) **Cf** Californium 98	(254) **Es** Einsteinium 99	(253) **Fm** Fermium 100	(256) **Md** Mendelevium 101	(254) **No** Nobelium 102	(257) **Lr** Lawrencium 103

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Preface

This book, Chemistry I, is specially tailored for Pre-University students in Universiti Malaysia Sarawak who intend to pursue their studies in either biological or physical science courses. It covers all the topics of the course PRK1016, Chemistry I which is offered in Semester 1. This book provides a useful transition from school to university level as well as a suitable reference for STPM, A-level or any other pre-university and first year university chemistry courses.

The applications of chemistry have changed due to the numerous modern challenges such as the creation of a greener environment, reduction of global warming, determination of genetic makeup to treat diseases and others. The basic concepts of chemistry still form the essence of the course. Therefore, the book starts with the basic scientific methods of handling data with special emphasis on all units of measurements to be included in the steps of calculations. Then there is the conservation of mass and mole concept applied to the amount of substances involved in a chemical reaction. Thermochemistry relates heat and chemical changes. The atomic properties, the periodic trends of elements and types of bonding determine the molecular structures which in turn result in behaviour of substances. We also emphasised on mechanistic studies of most organic chemical reactions as understanding the mechanism of reactions would make the subject more interesting and easier to explore.

As conceptual learning and problem-solving are fundamental approaches to the study of chemistry, there are examples of problem-solving after each chemistry concept in the book. We also provide exercises as the tools for students to become critical thinkers and to learn to apply principles and rules. The answers for the exercises and multiple choice questions are provided at the end of each topic.

Lastly, as all the chemistry concepts have been presented as simple and clear as possible, we hope that this book will help students to gain sufficient chemistry knowledge to meet the requirement of any science courses at university level.

The writers
Chemistry Unit
Centre for Pre-University Studies
UNIMAS

1 CHEMISTRY AND CHEMICAL NOMENCLATURE

1.1 Introduction

People, young or old, would always like to ask the question: "What is it made of?" This could be just natural curiosity, but it has led men to investigate the nature of the world around them. It has inspired great discoveries and led to advances in our knowledge.

1.2 Matter, Elements and Compounds

Chemistry deals with the properties and transformation of matter and the energy associated with those changes. One of the most important tasks of chemists is to study the nature of matter. Matter is anything that occupies **space** (volume) and has **mass** such as air, water, planets, and students. Matter occurs commonly in three physical states: solid, liquid or gas. It exists either as pure matter or impure matter. The pure matter can be an **element** or a **compound,** and impure matter is a **mixture** (Figure 1.1).

A complex substance can be broken down to simpler substance. A pure substance which cannot be chemically broken down into simpler substances is known as **element**. An element consists of only one type of particles and the particles can be either atoms or molecules.

Examples: Atoms: Na, K, Mg, etc
Molecules: O_2, H_2, Cl_2, etc

A **compound** is usually made up of two or more elements which are chemically bonded together so that the elements that make up the compound lose their identities and take on a new set of properties. A compound is made up of either molecules (molecular compounds) or ions (ionic compounds).

Examples: Molecular compound: H_2O, CO_2, NH_3, etc
Ionic compound: $NaOH$, NH_4OH, $NaCl$, $MgSO_4$ etc

A **mixture** is an impure matter consisting of two or more elements or compounds that are mixed without combining chemically. Each part of the matter in a mixture has its own identity (property). Each matter can be separated using physical or mechanical means.

There are two types of mixtures: heterogeneous mixtures and homogeneous mixtures. Heterogeneous mixtures are substances composed of two or more components that are not uniformly distributed throughout the system. They are immiscible, may be of different phase, and can be separated by mechanical means. Examples are sand and water (liquid and solid), oil and water (liquid and liquid), rock (solid and solid). A heterogeneous mixture is called a suspension or colloid.

Homogeneous mixtures are substances composed of two or more components that are uniformly distributed throughout the system. They are miscible, of a single phase, and cannot be separated by mechanical means. A homogeneous mixture is called a solution. Examples are vinegar (water and acetic acid are mixed evenly throughout), soft drinks, and glass.

An **atom** is the smallest neutral particle of an element that can take part in a chemical reaction. A **molecule** is a neutral particle made up of either atoms of the same element or atoms of different elements. For example, O_2 are molecules made up of atoms of same element; while CO_2 are molecules made up of atoms of different elements. An **ion** is a charged particle of either one atom, Na^+; or a group of atoms of different elements, SO_4^{2-}.

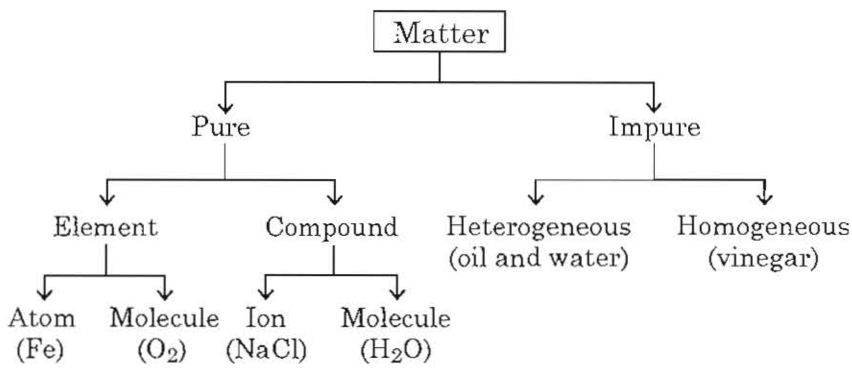

Figure 1.1 Classification of matter

Chemists observe two types of properties, physical and chemical, which are closely related to two types of change that matter undergoes. Physical properties are those that a substance shows by itself, without changing into or interacting with another substance. Physical properties include colour, melting point, density, electrical conductivity, and smell. A physical change occurs when a substance alters its physical form, not its composition.

$$\text{Water (solid)} \rightarrow \text{Water (liquid)}$$

Chemical properties are those that a substance shows as it changes into or interacts with another substance (or substances). Some examples of chemical properties are reactivity with acids, flammability, and corrosiveness. A chemical change (chemical reaction) occurs when a substance (or substances) is converted into a different substance (or substances).

$$\text{Water (liquid)} \rightarrow \text{Hydrogen (gas) + oxygen (gas)}$$

Exercise 1.1

1. Decide whether each of the following processes is a physical change or a chemical change, and explain briefly.
   (a) Dissolving sugar in water.
   (b) Dissolving sodium chloride in water.
   (c) Mixing acid and base.
   (d) An iron nail forming rust slowly in air.
   (e) Breaking a beaker.

1.2.1 Symbols and Formulae

The **symbols** of a chemical element are abbreviations that are used to denote a chemical element. Typically, they are one or two-letters long with the first letter capitalised. The elements with a single letter symbol are generally the common ones such as oxygen, or carbon, or they might be the only elements that start with that particular letter.

Most of the elements have double letter symbols. That second letter is usually the first non-common letter between elements that have names starting with the same letter. For example, chromium and chlorine both start with "C" and so does the symbol. They both have "h" for the second letter but the third letter is different; it is "l" for chlorine and "r" for chromium. Thus, the symbol for chlorine is Cl and for chromium is Cr.

The symbols of an element also represent specific amount of that element. For example, the symbol O represents one oxygen atom or 1 mole (6.02×10^{23}) of oxygen atoms; the symbol Na represents one sodium atom or 1 mole of sodium atoms.

Chemical Formulae represent chemical compounds showing the combination of the symbols of the constituents' elements. For example, the formula H_2O represents water or 1 mole of water molecule; the formula NaCl represents sodium chloride or 1 mole of sodium chloride.

1.3 Measurement in Scientific Study

In 1960, a metric system was established and accepted by scientists throughout the world. The units of this system are called SI units. Table 1.1 shows the SI system which is based on a set of seven fundamental units, or base units, each of which is identified with a physical quantity.

All other units, called derived units, are a combination of these seven base units. For example, the derived unit for speed, meter per second (m s^{-1}), is the base unit for length (m) divided by the base unit for time (s).

Table 1.1 SI Base Units

Physical Quantity (Dimension)	Unit Name	Unit Abbreviation
Mass	Kilogram	kg
Length	Meter	m
Time	Second	s
Temperature	Kelvin	K
Electric Current	Ampere	A
Amount of Substance	Mole	mol
Luminous intensity	Candela	cd

For quantities that are much smaller or much larger than the base unit, we use prefixes and exponential (scientific) notation. Table 1.2 shows the most important prefixes. Exponential (scientific) notation provides a much more practical way of writing very large or very small quantities. They are expressed as:

$$A \times 10^n \quad \text{where } 1 \leq A < 10 \text{ and n is an integer.}$$

Table 1.2 Common Decimal Prefixes Used with SI Units

Prefix	Symbol	Number	Word	Exponential Notation
tera	T	1,000,000,000,000	trillion	10^{12}
giga	G	1,000,000,000	billion	10^9
mega	**M**	**1,000,000**	**million**	10^6
kilo	**k**	**1,000**	**thousand**	10^3
hecto	h	100	hundred	10^2
deka	da	10	ten	10^1
-	-	1	one	10^0
deci	**d**	**0.1**	**tenth**	10^{-1}
centi	**c**	**0.01**	**hundredth**	10^{-2}
milli	**m**	**0.001**	**thousandth**	10^{-3}
micro	**μ**	**0.000001**	**millionth**	10^{-6}
nano	**n**	**0.000000001**	**billionth**	10^{-9}
pico	p	0.000000000001	trillionth	10^{-12}

Table 1.3 shows some useful SI quantities for length, volume, and mass, along with their equivalents in the English system. In chemistry, the most important volume units are liter (L) and milliliter (mL).

$$1\ L = 1\ dm^3 = 10^{-3}\ m^3$$

$$1\ mL = 1\ cm^3 = 10^{-3} dm^3 = 10^{-3}\ L$$

Table 1.3 Common SI – English Equivalent Quantities

Quantity	SI	SI Equivalents	English Equivalent	English to SI Equivalents
Length	1 kilometer (km)	1000 (10^3) meters	0.6214 mile (mi)	1 mile = 1.609 km
	1 meter (m)	100 (10^2) centimeters	1.094 yards (yd)	1 yard = 0.9144 m
		10^3 millimeters (mm)	39.37 inches (in)	1 foot (ft) = 0.3048 m
	1 centimeter (cm)	0.01 (10^{-2}) meter	0.3937 inch	1 inch = 2.54 cm
Volume	1 cubic meter (m^3)	1,000,000 (10^6) cubic centimeters	35.31 cubic feet (ft^3)	1 cubic foot = 0.02832 m^3
	1 cubic decimeter (dm^3)*	10^3 cubic centimeters	0.2642 gallons (gal)	1 gallon = 3.785 dm^3
			1.057 quarts (qt)	1 quart = 0.9464 dm^3
	1 cubic centimeter (cm^3)**	0.001 (10^{-3}) dm^3	0.03381 fluid ounce	1 quart = 946.4 cm^3 1 fluid ounce = 29.57 cm^3
Mass	1 kilogram (kg)	1000 grams	2.205 pounds (lb)	1 pound = 0.4536 kg
	1 gram (g)	1000 milligrams (mg)	0.03527 ounce (oz)	1 ounce = 28.35 g

*dm^3 = L; **cm^3 = mL